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Mobile Microwave Landing System (MMLS) User Interface

By

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This paper describes a user friendly Mobile Microwave Landing System (MMLS) interface design, based on menu schemes, that needs only a small number of function keys and limited display size. Although the design was developed for consideration in the local and remote control units for the MMLS, it is suitable for implementation on other control system interfaces where weight, display size, and/or the number of keys be kept to a minimum.

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SECTION 1

INTRODUCTION

The Mobile Microwave Landing System (MMLS) is currently being developed by Bell Textron to provide precision approach guidance for military aircraft. The control and monitoring functions of the MMLS are performed via ground-based control electronics units (CEUs) (figure 1) located at azimuth and elevation antenna sites. A remote control display unit (RCDU) (figure 2) is also being provided to monitor system status including maintenance alarm conditions generated by the CEU and to control either one of two MMLSs.

Bell's original design of the CEU keypad (figure 3) used 28 keys and a single row 20 character display to facilitate data entry and review. Most of the keys were dual-function and required that the operator enter appropriate data at the prompt using the keyboard. The parameter name and the space required for data entry were compressed into a one line alphanumeric display. This data entry and review scheme was difficult to read and was subject to operator error.

This paper presents an alternative control panel design and the resulting data entry and review scheme that could be used in the MMLS CEU. The alternative approach was developed with several objectives in mind. First, it should be easy for the user to operate and understand. Second, it should reduce hardware requirements for the CEU. Lastly, it should be flexible, providing a path for future additions to be incorporated in a clear and comprehensive fashion.

Section 2 discusses the basic requirements of the local control unit, remote control unit, and associated display panel. This section also deals with the complexity of the original control panel design.

Section 3 outlines an alternative control panel design that reduces the number of function keys required for data entry. The proposed data entry techniques minimize complexity by replacing the 28 single and dual function keys with four single function keys and by introducing a modified version of the menu structure that offers a high degree of understandability.

The major advantages and disadvantages of the new control panel design when compared to the proposed design are presented in section 4.

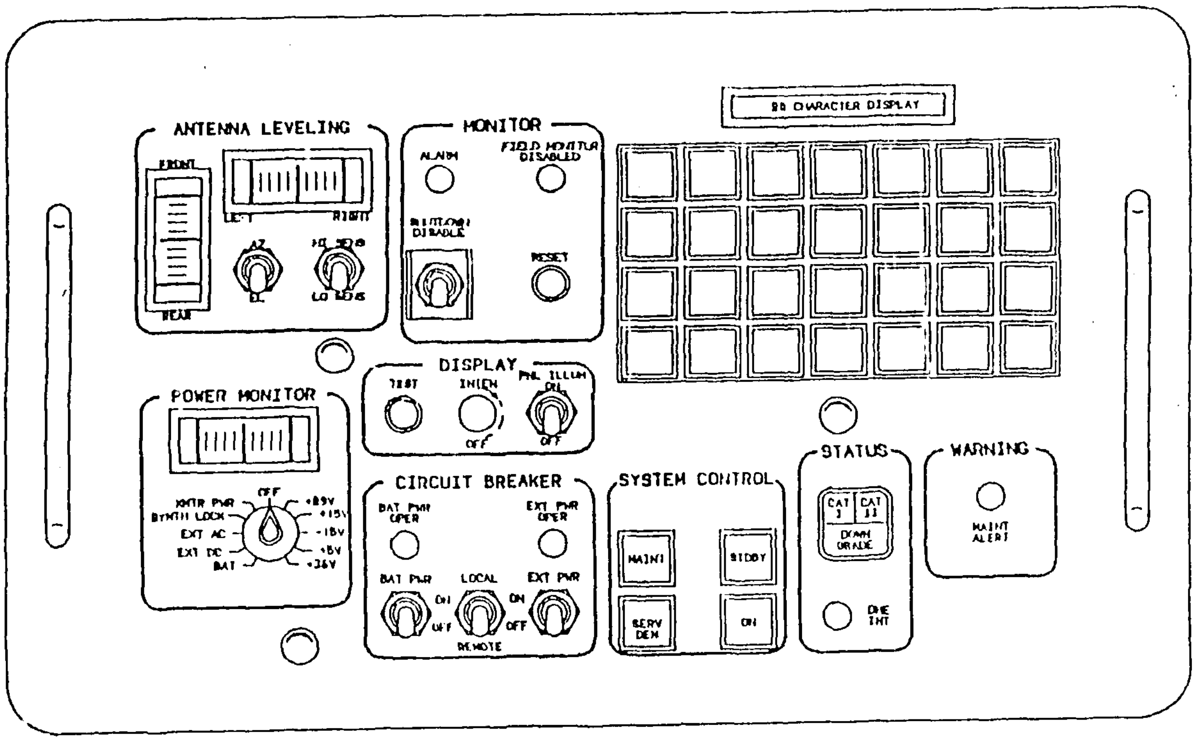
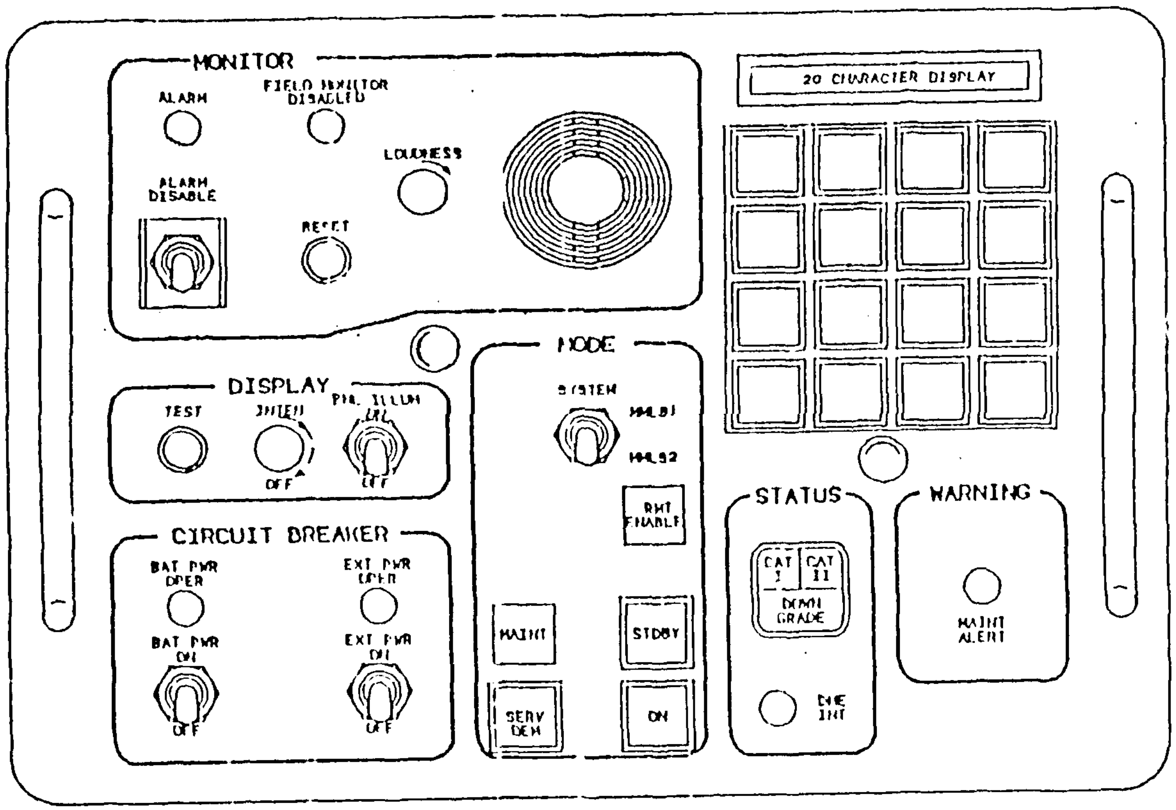


Figure 1. Control Electronics Panel



Fi;ure 2. Remote Control Display Panel

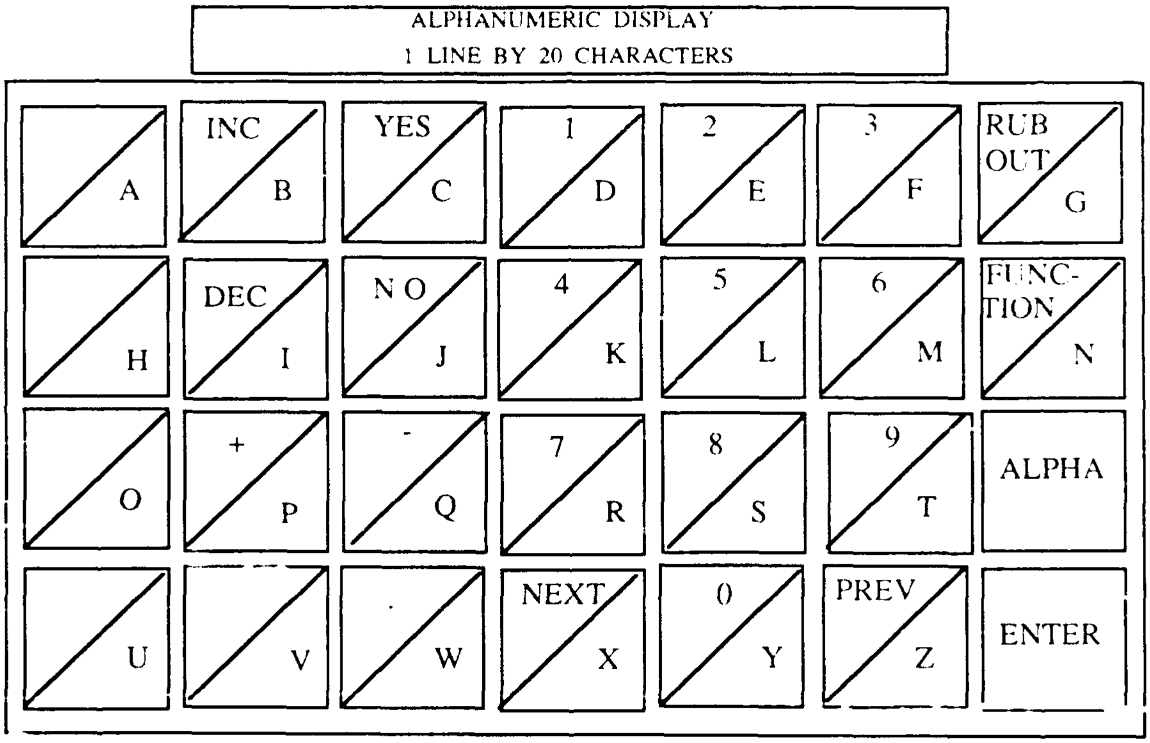


Figure 3. Keypad of MMLS CEU Control Panel

SECTION 2

BACKGROUND

The MMLS local control unit is required to provide for channel selection, alignment, selection of landing performance categories, field sensor bypass, and selection of equipment modes. The associated display unit is required to display monitor limits and the contents of field and factory data values (see tables 1 and 2). In addition to using menus or other single-keystroke data entry techniques, the displays are required to facilitate equipment alignment, data entry, and identification of Line Replacement Unit (LRU) failures.

Unlike the local control unit, data cannot be entered at the remote control and display unit, but it can be reviewed in all modes. A visual indication of a monitor alarm condition and the associated LRU failure is also required at the remote unit.

In the split-site configuration, the azimuth antenna and the Distance Measuring Equipment (DME) are located at the stop-end of the runway, whereas the elevation antenna is located at the side of the runway opposite the touchdown point. In this siting configuration, a local control and display unit is required with the approach azimuth equipment, and another with the approach elevation equipment. In the collocated configuration, that is, when DME, azimuth and elevation antennas are installed at the same location, a single local control unit provides control for the azimuth and elevation equipment.

The operating modes of the MMLS are: ON, OFF, STANDBY, MAINTENANCE, and SERVICE-DEMAND. Data entry is permitted only when the system is in the STANDBY or MAINTENANCE mode.

Table 1. Field Data Values

Parameters	Range of Values
AZ alignment	Telescope/encoder reading in DEG
AZ magnetic orientation	0 to 359°
AZ alignment with runway centerline	-20.47° to +20.47°
Performance select	Cat 1 or 2
Restart select	Cat 1 or 2
Channel select	500 to 699
AZ lower scan limit	-40 to -10 in 2 DEG steps
AZ upper scan limit	+10 to +40 in 2 DEG steps
EL lower scan limit	-0.4 to +7.1 in .1 DEG steps
AZ monitor limit	+100 to -50 in 10 percent steps
EL monitor limit	+100 to -50 in 10 percent steps
Echo suppression enabling level	10 to 100 dB
Echo suppression elevated level	0 to 6 dB
Echo suppression time	30 to 150 μsec
Field monitor #1 inhibit	Y or N
Field monitor #2 inhibit	Y or N
AZ to threshold distance	1 to 6300 meters
Minimum glide path	2 to 14.7°
AZ offset distance	+/- 511 meters
EL offset distance	+/- 511 meters
AZ to datum distance	0 to 8191 meters
MMLS ground equipment I.D.CHAR1	"A" through "Z"
MMLS ground equipment I.D.CHAR2	"A" through "Z"
MMLS ground equipment I.D.CHAR3	"A" through "Z"
Datum to threshold distance	0 to 1023 meters
MMLS datum elevation	+/- 4095 meters
EL antenna height	-6.3 to +6.3 meters
AZ antenna height	+/- 63 meters

Table 2. Preset Factory Data Values

Data Item	Value
Azimuth to MLS datum point distance	0 ft
MLS datum point to threshold distance	900 ft
Azimuth coverage limit (negative)	-40 deg
Azimuth coverage limit (positive)	+40 deg
Clearance signal type	Scanning beam
Azimuth status	Transmit 1
Elevation status	Transmit 1
DME status	Transmit 01
Minimum glidepath	3 deg
Azimuth beamwidth	2.8 deg
Elevation beamwidth	2.2 deg
DME distance (to MLS datum point)	0 ft
DME offset	150 ft
Azimuth antenna offset	150 ft
MLS ground equipment identification	
Character 2	M
Character 3	L
Character 4	S
DME echo suppression enabling level	20 dB
DME echo suppression elevated level	3 dB
DME echo suppression time	50 μsec

Data relating to the elevation site are entered at the elevation CEU. System, DME, and azimuth data are entered at the azimuth CEU. Preset factory data can be selected for initializing parameters in the collocated configuration. In the split site configuration, the operating siting conditions must be entered. The required entries and their range of permissible values are shown in table 1. The level sensor, azimuth and elevation alignment data entries represent measured values obtained during the leveling and alignment process.

Figures 1 and 2 show Bell's original control panel designs of the CEU and RCDU, respectively. A more detailed view of the keypad is shown in figure 3. In this design, Bell used 28 keys and a single row 20 character display to facilitate data entry and review. Most of the keys were dual-function, and required that the operator enter appropriate data at the prompt using the alphanumeric keypad (see figure 3).

After each data entry, which required manually typing all the data, control was returned to a Function Menu. Once inside the Function Menu the user had four alternatives:

1. Proceed to the next available function using the <NEXT> key.
2. Return to the previous choice using the <PREV> key.
3. Exit the Function Menu by pressing the <FUNCTION> key.
4. Execute the function listed on the display by pressing the <YES> key. A <NO> response simply left everything unchanged.

Also, if the operator inadvertently changed the existing data, pressing the <ENTER> key at all data prompts would lead the operator back to the Function Menu without modifying the data.

Use of large numbers of keys not only adds to the complexity of the design, but also increases hardware/software requirements. An increased number of keys necessitates a corresponding increase in drive electronics and support software. These increases in hardware/software requirements not only affect the reliability of the system, but could also cause increases in the development and the production cost of the control unit. In addition, the data entry and review scheme proposed by Bell required an operator to be familiar with the valid responses to displayed instructions. It is desirable that the operation of a mobile system not depend on either the availability of an experienced operator or an instruction manual.

The display size proposed by Bell (single row 20 characters long) had insufficient space to display even an abbreviated version of the parameter name and the associated values (see table 1). It is important that the display be capable of accommodating adequate information for an operator to comprehend the menu instructions without the assistance of an instruction manual. In order to avoid incorrect data entry, the operator should be able to view the current value of the parameter and the permitted range of values associated with that parameter. The display should also provide a clear indication of the different operating modes of the menu scheme, that is, whether or not the operator is in data review or entry mode.

It was considered unlikely that the proposed display and keyboard design would provide a user friendly user system interface -- an essential feature for a mobile system. Because of the undesirable complexity of Bell's approach to the MMLS control panel design, an alternative approach was considered.

SECTION 3

ALTERNATIVE APPROACH

3.1 OVERVIEW

As stated in the preceding section, the design of a user system interface for the MMLS should be such that the system operation can be effected without performing complex data entry tasks. Furthermore, the menu instructions and the displayed information should be self-explanatory. A cluttered keyboard accompanying a complex menu instruction set would make it somewhat difficult for an operator to perform the routine deployment task. An alternative design outlined below minimizes the overall complexity of the control panel design. This design is also based on a menu-driven interface, but uses a two-line alphanumeric display controlled by only four keys.

As discussed later in this section, a high degree of understandability is maintained in spite of the substantial reduction in the number of keys to perform the data review and entry function. The reduction of the number of keys from 28 (mostly dual-function) to four single function keys will lead to some reduction in drive electronics and associated support software. This reduction in CEU hardware/software requirements should result in greater reliability of the system and a reduction in development and production costs.

The open nature of the menu approach offers ease of adaptability for future additions. Each menu can have more items added to it at any time without changing the presentation of any previous features. The remainder of this section outlines an alternative control and display concept.

3.2 PHYSICAL DESCRIPTION

The keypad and display area layout of the control panel shown in figure 3 can be simplified and rearranged in a manner shown in figure 4. The keyboard consists of four keys entitled "MENU," "UP-ARROW," "DOWN-ARROW," and "ENTER." In addition to the keyboard, a prompt (>) appears in the display area and, depending upon the status of the prompt (steady or flashing), the functionality of the "ARROW" key changes. A flashing prompt indicates data entry mode and "ARROW" keys permit changes to the displayed parameter values. A steady prompt indicates parameter selection mode and "ARROW" keys permit scrolling through the list of parameters. The functions of the four keys are defined below:

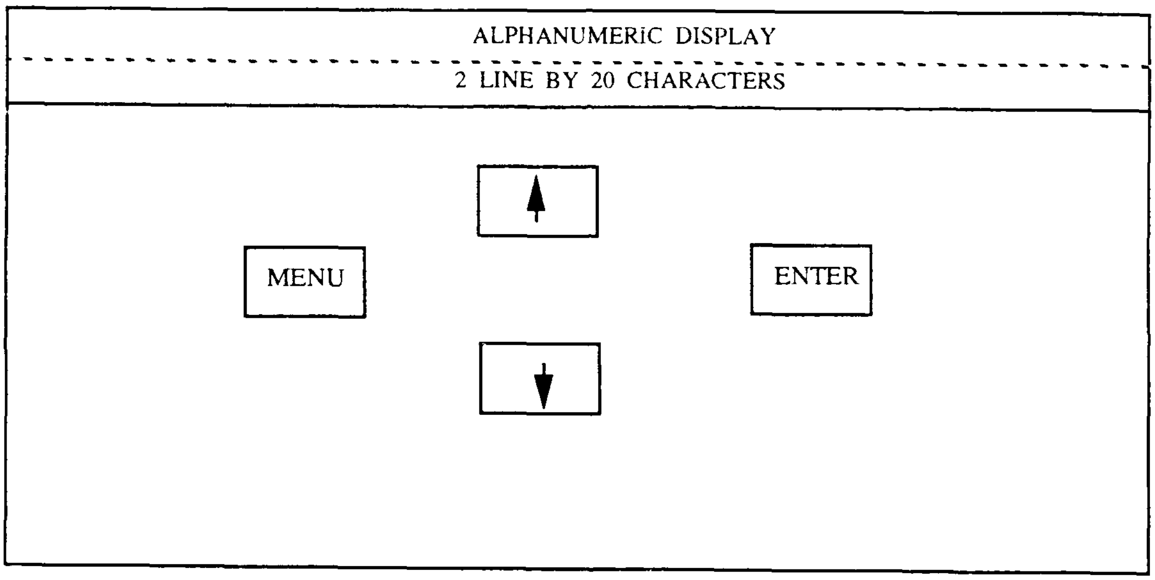


Figure 4. Alternative Keyboard and Alphanumeric Display Area for the MMLS Control Panel

UP-ARROW	Depression of this key moves the user up one position in the list of current menu options, or in the list of possible settings for a selected menu item.
DOWN-ARROW	Depression of this key moves the user down one position in the list of current menu settings, or in the list of possible settings for a selected menu item.
MENU	Depression of this key serves to exit the current menu, or, if a parameter is currently being entered, to terminate parameter entry.
ENTER	Depression of this key serves to select the currently indicated (via >) menu item, or, if the menu item has already been selected, to complete the entry of a new value for the selected parameter.

This proposed keyboard layout not only reduces the number of keys from 28 to 4, but relieves the user from being a proficient typist to enter each character of required information. In order for this approach to work, an appropriate menu structure for the review and entry of data must be developed. More will be said about the required menu structure in a later section. However, it should be noted that the functions of the four keys are consistent no matter how many menu items exist, or if new menu items are added in the future.

As shown in figure 4, a second line of 20 alphanumeric characters is also proposed. This change allows an abbreviated version of parameter name and associated range of values to be displayed in the first line. The second line of the display would then be used to display the prompt (>) and to review the current value of the particular data item, including changes as they are being made. Although the second line of the display could be slightly smaller than 20 characters, standard multiple-line displays are generally not available in unequal lengths. The spare space (approximately eight characters) could be used for displaying various maintenance alarm conditions and for indicating the current operating mode. The availability of a second line that allows the display of a valid range of parameter values should reduce chances of operator input error. The following paragraphs outline a menu concept for the MMLS and provide an example of how the alternate keyboard and display panel would be used in conjunction with that concept.

3.3 OPERATIONAL SCHEME

Figure 5 presents a menu flow diagram for the MMLS keyboard. Keyboard operation and display sequences are discussed through examples in the following sections.

It is assumed that power has been applied, a proper password has been entered, and that the system is in an appropriate mode for each of the sequences discussed. The first series of displays would relate to selecting the proper function as shown below.

```
|FUNCTION SELECT     |
|>  REVIEW DATA      |

       |     ^
       v     |

|FUNCTION SELECT     |
|>   ENTER DATA      |

       |     ^
       v     |

|FUNCTION SELECT     |
|>     LRU STATUS    |
```

By depressing the up- or down-arrow keys, the user can display the desired function on the screen. The ENTER key will then be depressed to select the displayed function. To return to the top-most screen, the user will depress the MENU key. More than two minutes of inactivity will turn the display off. The display can be restored to its previous state by activating any of the data entry keys or the mode selection switches.

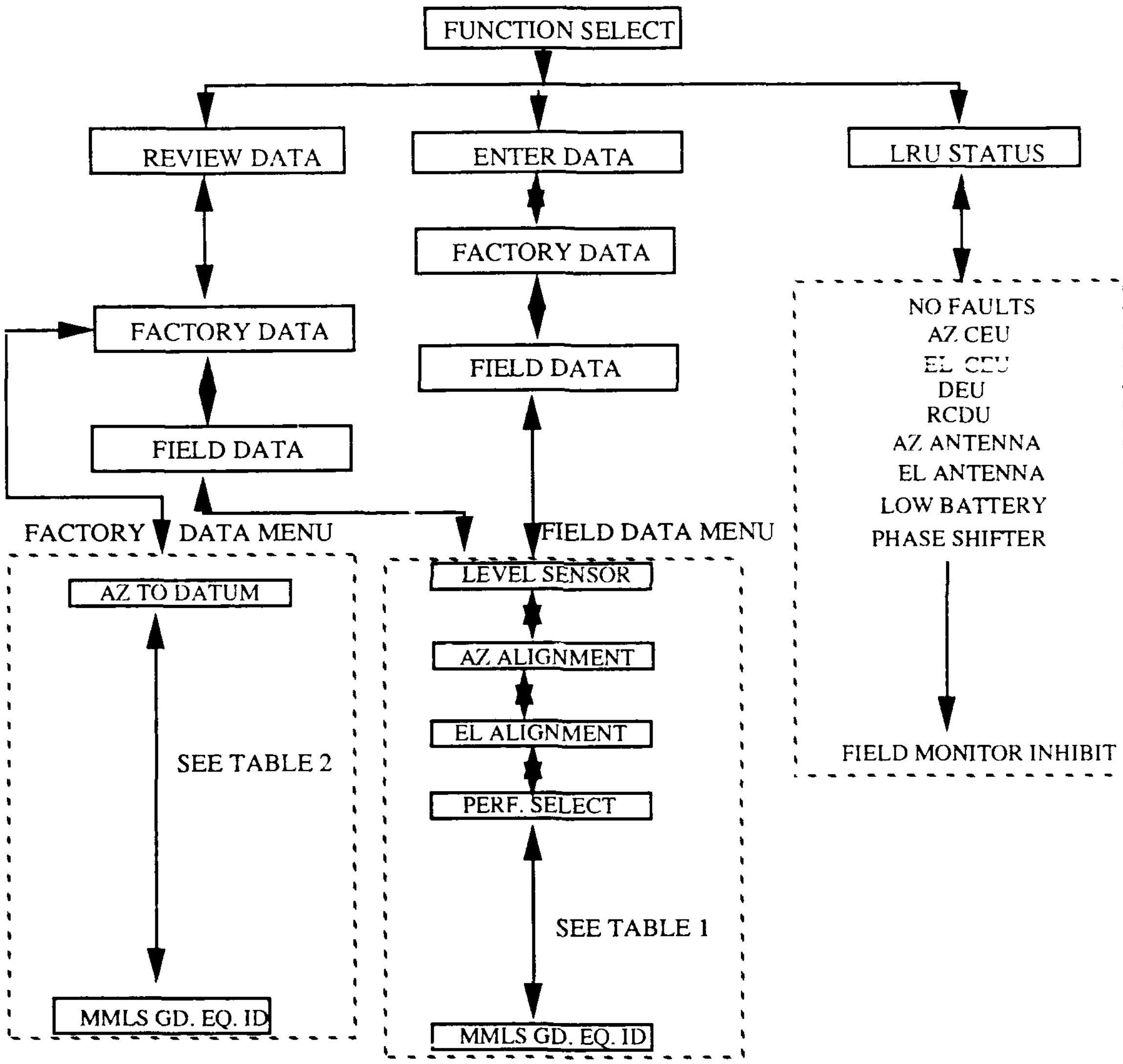


Figure 5. MMLS Menu Flow Diagram

3.3.1 Review Data

When the user selects "REVIEW DATA" from the function select screen, the following sequence of screens will be displayed.

```
|REVIEW DATA          |
|>   FIELD DATA       |

          |     ^
          v     |

|REVIEW DATA          |
|>   FACTORY DATA     |
```

Selection between the two screen displays can simply be made by using up or down arrow keys. The desired function can then be entered by depressing the ENTER key. The user can then, by use of ARROW keys, scroll through the various field parameters to review current entries. In a similar manner, "FACTORY DATA" can be reviewed.

3.3.2 Enter Data

When the "ENTER DATA" mode is selected from the function select screen, the first screen the user sees will be:

```
|ENTER DATA           |
|>   FACTORY DATA     |
```

By depressing the up or down arrow keys, the screen display can be changed as shown below:

```
                        |ENTER DATA           |
Prompt (steady)         |>   FACTORY DATA     |

                                  |     ^
                                  v     |

                        |ENTER DATA           |
Prompt (steady)         |>   FIELD DATA       |
```

At the desired screen display, the user will depress the ENTER key to select the function displayed. If the user selects "FACTORY DATA", the screen display will change to reflect the data entry mode, as shown below.

```
                          |ENTER DATA          |
Prompt  (flashing)        |>   FACTORY DATA    |
```

At this point the user can depress the ENTER key to establish the factory data as operating parameter values.

If, on the other hand, the user chooses "FIELD DATA", the screen display will change as shown below. The sequence of the display screens will follow the list given in table 1.

```
                          |LEVEL SENSOR        |  Parameter selection mode
Prompt (steady)           |>    ...DEG         |
                                                     <ENTER>

                          |LEVEL SENSOR        |  Data entry mode selection
Prompt (flashing)         |>    ...DEG         |
                                                     <ENTER>

                          |LEVEL SENSOR        |  Parameter selection mode
Prompt (steady)           |>    ...DEG         |

                                  |     ^
                                  |     |
                                  v     |

                          |MMLS GD.EQ.ID CHAR 3|
                          |> ....              |
                              ^
                              |
                          Most recent entry
```

In the case of "LEVEL SENSOR", "AZ ALIGNMENT", or "EL ALIGNMENT", the measured data will be displayed on the second line of the screen. These data can then be accepted by depressing the ENTER key. Once the data is entered, the prompt, ">", will become steady. At this point, the user can depress up- or down-arrow keys to cycle through the list of parameters. When the desired parameter is on the screen, the user can depress the ENTER key to flash the prompt again, indicating data entry mode. While the prompt is flashing, depression of up- or down-arrow keys will cycle the current parameter value within the limits indicated at the top-right corner of the display. Any predefined discrete steps associated with a particular parameter can be automatically taken into account while using the up or down-arrow keys for incrementing or decrementing the displayed parameter value. Once the desired parameter value is selected on the screen, depression of the ENTER key stores the displayed value as an operating parameter and the user is returned to the parameter selection mode indicated by prompt ">" (steady).

3.3.3 Line Replaceable Unit (LRU) Status

When the "LRU STATUS" mode is selected from the function select screen, the user will see the following screen. If no LRU faults have been detected, the message on the second line will simply be "NO FAULTS". If fault conditions exist, then fault messages (see figure 5) can be displayed by the use of up or down-arrow keys.

```
LRU STATUS
>   NO FAULTS
```

SECTION 4

ADVANTAGES AND DISADVANTAGES

The key advantages and disadvantages of the design presented in this paper in comparison to Bell's original design are outlined below:

4.1 ADVANTAGES

- The number of keys used on the CEU front panel for data review or entry is reduced from 28 to 4, a considerable saving in hardware and associated support software. This reduction in CEU hardware/ software should result in greater reliability of the system.

- Use of single keys rather than dual function keys reduces the chance of data entry error. Also, use of fewer keys on the control panel makes it possible to increase the physical space between the keys without increasing the overall size of the panel. Increased spacing between keys is a desirable feature when arctic mittens are in use.

- Use of two display rows provides more space for displaying function (or parameter) title, data values, and current entries. It permits allocation of separate rows of the screen for data or command entry and for preset information, a display format that should cause less confusion to the operator.

4.2 DISADVANTAGES

- The use of two rows of 20 characters compared to Bell's single row 20-character display is a modest increase in hardware.

- The design is intended to make it somewhat difficult for an operator to get into the data entry mode for this application. This difficulty can be alleviated by adding a separate hardware key labelled "DATA MODE" for direct access to data entry mode. Also, the addition of a key labeled "SCROLL SPEED" could further enhance the user interface by allowing rapid selection of field parameter values, albeit at a cost of additional hardware.

It has been shown that the hardware and software design of the control system for use in a mobile environment can utilize four single function keys rather than 28 mostly dual function keys for data entry and review and still be user friendly. In addition, in a mobile system where weight and size is of utmost importance, implementation of the alternative menu driven approach presented in this paper can lead to an overall reduction in hardware. Reduction in hardware (keys and drive electronics) and associated support software could improve reliability, reduce development cost and should also lead to saving in production cost of the control electronics unit and the remote control display panel.